APPLICATION OF DIFFERENT RADIATION PARAMETERIZATION METHODS TO LEAF WETNESS DURATION MODEL DEVELOPMENT

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Abstract

Leaf wetness duration (LWD) is very important agrometeorological parameter in the spreading of plant diseases. In spite of its importance there is no standard available for LWD monitoring. Several attempts have been made to build models in order to simulate LWD. For the plant leaf surface wetness estimation of different meteorological and plant parameters are needed. Their availability in space and time frequently represents one of the major constraints. We measured and simulated leaf wetness formation to test the ability of model to predict wetness formation as a function of six different meteorological parameters. Special objective of our study was to compare model behavior by different long wave radiation parameterization methods (flux emissivity method (Stephens, 1984), Brutsaert method (Crawford, 1998), Marks and Dozier method (Zeller, 2002), Swinbank method (Crawford, 1998)). The experiment was performed in 2005 at Bilje meteorological station which is set in the SW part of Slovenia. The meteorological data were carried out from Bilje meteorological station and from Udine vertical sounding measurements. The best performance of LWD model was observed with the usage of Brutsaert method. It is suggested that this method should be used as alternative for points where atmospheric radiation measurements are not available.

Introduction

From an epidemiological point of view, leaf wetness duration is important precondition influencing the outbreak and severity of plant disease. Continuous leaf wetness measurements are rare and non-standardized. LWD estimations can help us to determine this important parameter in places, where there are no measurements available. LWD models are mainly based on leaf energy balance and often provide information about the causes of leaf wetness (rain, dew or fog). Very important part of energy balance represents atmospheric radiation. The focus of this paper is to validate different radiation parameterizations that can be used to quantify LWD.

Material and methods

In the present study model TOL (EARS, 2006) was adapted by employing four long – wave radiation methods: flux emissivity method, Brutsaert method, Marks and Dozier method, Swinbank method.

Flux emissivity method involves using a pre - calculated emissivity function, which represents the frequency integrated absorption spectrum of water vapor (Stephens, 1984). For the simplification of radiative flux calculation the atmosphere was divided into horizontal layers. The number of layers is determined with vertical sounding measurements. The closest vertical sounding data for calculation of atmospheric radiation in Bilje were carried out from Udine meteorological station. Air temperature, air pressure and water vapor data were obtained from vertical measurements. Different flux calculation approaches for clear (flux j_{clear}) and cloudy sky (flux j_{cloud}) were used. Cloud fraction and cloud types data were obtained from synoptical meteorological station Bilje. In case of partial cloudiness the radiation flux j_{down} was calculated according to equation 1.

$$j_{down} = j_{clear}(1 - n/N) + j_{cloud}\,n/N \ , \quad (1)$$

where n/N represents cloud fraction.

Simpler methods like Bruesaert method, Marks and Dozier method and Swinbank method for calculation of atmospheric radiation include estimation of atmospheric emissivity using data from ground weather station measurements. The amount of downwelling long - wave radiation is determined by the effective clear sky emissivity ε_c and the near surface temperature T (K) according to equation 2.

$$j_{clear} = \varepsilon_c \sigma T^4 \qquad (2)$$

σ is Stefan-Boltzman constant.

Brutsaert parameterized emissivity ε_c for clear sky radiation with

$$\varepsilon_c = 1.24(e/T)^{1/7} \qquad (3)$$

where e represents the water vapor pressure (mbar). Since the presence of clouds significantly increases effective emissivity, Czeplak - Kasten parameterization (Czeplak and Kasten, 1987) was used for clouds effect includance (equation 4).

$$j_{down} = j_{clear}((1 + a_l C_l^{2.5}) + (1 - C_l)a_m C_m^{2.5} + (1 - C_l)(1 - C_m)a_h C_h^{2.5}) \qquad (4)$$

where C_l, C_m and C_h represent cloud fraction on low, middle and high level, a_l, a_m and a_h are empirical coefficients, that depend on air temperature T.

Marks and Dozier method modified Brutsaert parameterization of ε_c for clear sky radiation (equation 5).

$$\varepsilon_c = 0.642(1.38e(mbar)^{-1}/(T(K)^{-1} + 0.0068Z(m)^{-1}))^{1/7} \cdot p/p_0 \quad (5)$$

where Z represents the altitude of the station (in meters), p is the air pressure (measured at the station) and p_0 is standard air pressure at sea level (1013.25 mbar). The effect of cloudiness is included in equation 6.

$$j_{down} = j_{clear}(1 + 0.23n/N) \qquad (6).$$

Swinbank parameterized clear sky emissivity according to equation 7.

$$\varepsilon_c = 9.36 \cdot 10^{-6} T^2 \qquad (7).$$

Results

TOL model output showed strong dependence on method used for atmospheric radiation parameterization. In Table 1 comparison results of measurements with observed daily duration of leaf wetness during vegetation season in 2005 are presented (MBE – mean bias error, RMSE – root mean square error, R^2 - determination coefficient for linear regression). The best agreement between observations and calculations of leaf wetness duration in Bilje was achieved by using Brutsaert method. LWD was underestimated if the flux emissivity method and Marks and Dozier parameterization for TOL were used (low values of MBE). Use of Swinbank method overestimated daily LWD in Bilje (highest value of MBE). Calculation with Brutsaert method also pointed out the smallest value of RMSE. Determination coefficient for regression line (Figure 1) indicated quite a good fit for Brutsaert method. A uniform distribution of points around regression line was detected.

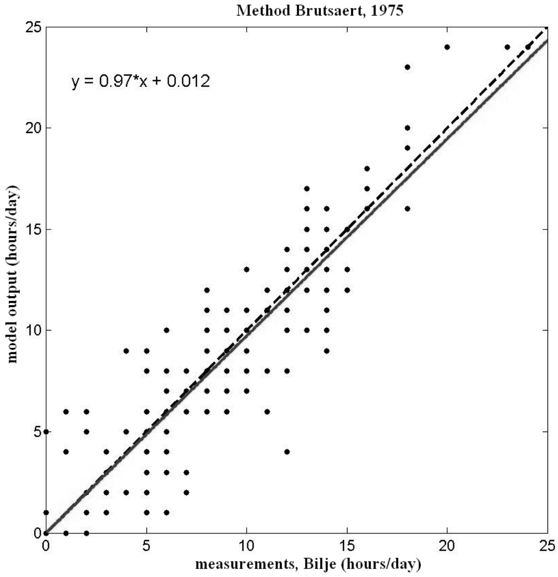

Fig.1 - Comparison between observed and calculated daily LWD, using the Brutsaert (1975) emissivity scheme for TOL model input. The data were obtained from the automatic weather station in Bilje (during vegetation season in 2005). Continuous line represents the results of the linear regression, while the dashed line represents a "perfect fit" line.

Brutsaert method showed the best performance by categorical predictions. The "percent correct" value is a ratio between correct model predictions and total model predictions of leaf wetness. This value turned out to be 90 %, when using Brutsaert scheme. Bias determined whether the same fraction of events (the leaf is wet) are both predicted and observed. For Brutsaert method bias was 0,97 (perfect value of bias is 1).

Method	**MBE**	**RMSE**	**R^2**
Flux emissivity	-2.18	4.13	0.65
Brutsaert	-0.2	2.16	0.84
Marks and Dozier	-2.40	4.10	0.66
Swinbank	1.66	3.21	0.77

Table 1 – Statistics of observed and modeled LWD (TOL model) using four different atmospheric radiation parameterizations.

Conclusions

The comparison between TOL model and observations of LWD in Bilje showed that the Brutsaert method with Czeplak – Kasten parameterization of the effect of cloudiness to radiation conditions is the most appropriate for estimating atmospheric long - wave radiation for TOL model input. All other methods under or over estimated daily LWD. For flux emissivity method vertical sounding data are needed. According to the results the importance of representative microclimatic radiation data was stressed. In the case of their unavailability Brutsaert method should be used as alternative.

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